TESTS OF HATCHERY FOODS FOR SALMON 1951

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 86

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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TESTS OF HATCHERY FOODS FOR SALMON 1951

by

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INTRODUCTION

The 1951 feeding trials at the Entiat Salmon-Cultural Laboratory were a continuation of the feeding experiments reported by Burrows *et al.* (1951), Robinson *et al.* (1951a) and Robinson *et al.* (1951b). In the present evaluations both blueback salmon (*Oncorhynchus nerka*) and chinook salmon (*O. tshawytscha*) were used as the test animals. The primary purpose of these and the previous trials was the development of adequate diets for the artificial propagation of salmon from food products either unfit or undesirable for human comsumption. All products tested were commercially available or could be made available in sufficient quantity to provide an adequate source of fish food.

Three separate but related experiments were conducted. The first consisted of a 12-week cold-water phase and a 12-week warm-water phase. In the latter only a portion of the diets fed in the first phase were carried through for the 24-week period. The second experiment was composed of diets fed for a 12-week warm-water period and was more exploratory in nature. In both the first and second experiments blueback salmon were the test animals. The third experiment was of 24 weeks' duration during both the cold- and warm-water periods. For the first time in these diet studies chinook salmon were used as the test animals.

Results of the 1951 trials provided evaluations of beef lung, whale liver, arrow-toothed halibut flesh, and herring flesh, both as single rations and in combination with other products, as diet components for salmon. Additional information was secured on the value of preserved salmon eggs and tuna liver in composite diets. Toxicities probably due to hypervitaminosis A developed in certain diets, and the symptoms were noted. It was demonstrated that the mortalities which occur from feeding meals at cold water temperatures were probably not due to the unavailability of the protein or certain amino acids, but possibly to a vitamin deficiency. No differences could be demonstrated between the nutritional requirements of chinook and blueback. Three potential production diets were developed. These diets contained no beef liver yet produced growth rates equal to or better than the standard control diet containing beef liver, with no evidence of nutritional inadequacy.

To evaluate results, control diets were established in each experiment. Within groups of each experiment, changes in the diets were made either by substitution or by supplementation. In the first procedure, a single product was withdrawn in part or in its entirety and another product was substituted. In the second, a combination of products was supplemented by the addition of another material and the entire previous combination reduced a proportionate amount. In the presentation, comparisons were made only between diets within an experiment. Each experiment has been presented separately and comparisons made between experiments by deduction based on the relative standings of comparable diets with reference to their individual controls.

Conditions of Experiment

The techniques, equipment, and methods used in the experiments with blueback salmon have been described in detail by Burrows et al. (1951). No changes in procedure or methods of analysis were made. Each diet was fed to duplicate troughs of fish stocked at 500 grams each in the first experiment and 1,000 grams each in the second experiment.

In the experiment with chinook salmon certain variations in equipment and techniques were introduced. It has been demonstrated by Johnson and Gastineau (1952) that chinook salmon grow at a retarded rate in troughs. The same authors and Palmer et al. (1952) show that in 6-foot circular tanks, chinook salmon grow at the same rate as those reared in large raceways or in Foster-Lucas ponds. The reduction in rate of growth in troughs precluded the use of troughs for diet experiments with chinook salmon. With the transfer of the Salmon-Cultural Laboratory from Leavenworth to Entiat it was possible to install 6-foot circular tanks in the hatchery. Since it had been demonstrated that this size of tank did not retard the growth rate of chinook, it was then possible to conduct feeding trials with this species. The circular tanks were substituted for the standard deep troughs in the third experiment. Each tank was stocked with 500 grams of fish, and the diets were fed to duplicate tanks.

The amount fed per day was determined by reference to feeding charts developed for chinook salmon as shown in Table 1. The percentage of food fed in proportion to the body weight was much less for chinook than it was for blueback salmon at the same water temperature and fish size.

With these exceptions, the techniques, equipment, and methods used in the three experiments were identical, and comparable to those of previous trials.

Results of Experiments

Each of the three experiments was designed for a different purpose. The first experiment was a test of products previously evaluated in feeding trials conducted at this laboratory or by other investigators. Its primary purpose was to develop production diets. The second experiment was more exploratory in nature, designed to test new products and to measure their potentialities as components of salmon diets. The third experiment, in which chinook salmon were used, was designed to determine if differences existed between the nutritional requirements of blueback and chinook salmon and, on the assumption that such differences existed, to attempt to fortify suspect diets to prevent the development of anemia and to increase the growth rate.

First Experiment, Cold-Water Phase

The cold-water phase of the first experiment, using blueback salmon as the test animals, was conducted for a 12-week period at an average

Table 1. Feeding chart for chinook salmon expressed as the percentage of the body weight to be fed per day

Average water temperature °F	Number of fish per pound 2,500-1,000	1,000-300	300-150	150-90	90-40	40-10	10-under
40	5.4	4.6	4.1	3.6	2.7	1.7	1.2
41	5.6	4.8	4.2	3.7	2.9	1.8	1.3
42	5.9	5.0	4.5	3.9	3.0	1.9	1.4
43	6.2	5.3	4.7	4.1	3.2	2.0	1.4
44	6.4	5.5	4.9	4.3	3.3	2.1	1.5
45	6.7	5.8	5.2	4.6	3.5	2.2	1.6
46	7.0	6.1	5.5	4.8	3.7	2.3	1.7
47	7.4	6.4	5.7	5.0	3.8	2.5	1.8
48	7.7	6.7	6.0	5.3	4.0	2.6	1.9
49	8.0	7.0	6.3	5.5	4.2	2.7	2.0
50	8.4	7.4	6.6	5.8	4.4	2.9	2.1
51	8.8	7.7	6.9	6.1	4.6	3.0	2.2
52	9.3	8.1	7.3	6.4	4.9	3.2	2.3
53	9.7	8.5	7.6	6.7	5.1	3.3	2.4
54	10.2	8.9	8.0	7.0	5.3	3.5	2.5
55	10.6	9.3	8.4	7.4	5.6	3.6	2.6
56	11.1	9.7	8.7	7.7	5.8	3.8	2.8
57	11.6	10.1	9.1	8.1	6.1	4.0	2.9
58	12.1	10.6	9.6	8.5	6.4	4.2	3.0
59	12.6	11.1	10.1	8.9	6.7	4.4	3.2
60	13.6	11.6	10.5	9.3	7.0	4.7	3.3
61	14.6	12.1	11.0	9.7	7.3	4.9	3.4
62	15.6	12.6	11.5	10.1	7.6	5.1	3.5
63	16.6	13.1	12.0	10.5	7.9	5.3	3.6

water temperature of 44.5° F. The response of blueback salmon to different diets varies with marked changes in water temperatures. Certain of these phenomena have been described by Burrows et al. (1951) and confirmed by Robinson et al. (1951a). By definition average water temperatures below 45° F. are considered cold water and average water temperatures above 50° F. are regarded as warm water. Because of the variation in response to diets at different temperatures the design of the experiments was such as to test diet components at either cold water, warm water, or a combination of both phases of temperature.

A summary of the cold-water phase of the first experiment is given in Table 2. The diets of this part may be divided into three main groups. In the first group (Diets 1 through 7 and Diet 12) evaluations were made of individual components and limited combinations, usually two, of the components. In the second group (Diets 8 through 11) variations in the standard meat-viscera mixture were tested. In the third group (Diets 13 through 18) an attempt was made to determine the cause for the high mortalities encountered when feeding salmon meals during periods of cold water.

Eight diets composed the first group. Beef liver (Diet 1) was included as the standard control. Beef lung was fed at the 100 percent level (Diet 2) and in combination with equal parts of beef liver (Diet 4) and hog liver (Diet 5). Equal parts of hog liver and beef liver in combination (Diet 3) were included for comparative purposes. Salmon viscera in combination with hog liver (Diet 6), hog liver and hog spleen (Diet 7), and tuna liver (Diet 12) completed the diets in this group.

Beef lung was the only component in these trials which had not been tested previously by this laboratory. McCay et al. (1931) found beef lung comparable to beef liver and kidney when fed at the 25 percent level in combination with dry feeds. He concluded that beef lung contained the anti-anemic factor. Titcomb et al. (1929) could demonstrate no difference in growth rates between trout fed diets consisting of 100 percent each of either beef spleen or hog liver or beef lung. Wales and Moore (1938) came to the same conclusions on diets consisting of either beef liver, beef heart, or beef lung. Lord (1935) found that lungs and spleen gave inferior growth in comparison to beef, hog, or sheep liver.

Previous experiments at this laboratory (Burrows et al. 1951) indicated that a combination of 50 percent each of beef liver and hog liver was superior to either beef or hog liver fed separately or in combination with 50 percent of hog spleen. These results were confirmed in the present trials in which the beef liver - hog liver combination (Diet 3) produced a significantly greater gain in weight than did beef liver (Diet 1).

Beef lung at the 100 percent level (Diet 2) produced gains in weight superior to those of beef liver (Diet 1) and comparable to the

TABLE 2.--Summary of 1951 feeding trials with blueback salmon--First Experiment, Cold-water phase

Initial number per trough: 1,157 fish
Initial weight per trough: 500 gr.
Initial average weight per fish: .43 gr.
Initial number per pound: 1,052 fish
Period: 4/4/51 to 6/26/51
Temperature: average for 12 weeks, 44.5°F.

Diet No.	Components	Percentage Composition	Mean diet weight at the end of 12 weeks in grams	Per cent mortality 12 weeks	Conversion 12 weeks	Hemoglobin g/100 ml. blood	Deficiency Symptoms
1	Beef liver	100.0	2,176	1.08	3.19	13.8	None
2	Beef lungs S1/	100.0	2,402	1.90	2.99	10.7	None
3	Beef liver S Hog liver	50.0 50.0	2,420	.91	2.87	15.6	None
4	Beef liver S Beef lung	50.0 50.0	2,406	.82	3.04	13.0	None
5	Hog liver S Beef lung	50.0 50.0	2,498	1.30	2.89	14.1	None
6	Hog liver S Salmon viscera	50.0 50.0	2,740	.99	2.75	13.0	None
7	Hog liver S Hog spleen Salmon viscera	40.0 10.0 50.0	2,744	1.38	2.76	12.5	None
8	Beef liver S Hog liver Hog spleen Salmon viscera	22.2 22.2 22.2 33.4	2,668	.95	2.79	14.1	None
9	Beef liver S Hog liver Hog spleen Salmon eggs (frozen)	22.2 22.2 22.2 33.4	2,854	1.38	2.66	13.8	None
10	Beef liver S Hog liver Hog spleen Preserved salmon eggs	22.2 22.2 22.2 33.4	2,606	1.25	2.79	12.0	None
11	Tuna liver S Hog liver Hog spleen Salmon viscera	22.2 22.2 22.2 33.4	2,584	1.21	2.87	12.8	None
12	Tuna liver S Salmon viscera	50.0 50.0	2,010	.95	3.68	13.3	None
13	Beef liver S Hog liver Hog spleen Salmon viscera Sal. visc. meal2/	20.0 20.0 20.0 30.0 10.0	2,959	2.20	2.58	13.0	None
14	Beef liver S Hog liver Hog spleen Salmon viscera Predigested sal. visc. meal3/	20.0 20.0 20.0 30.0 10.0	2,894	3.46	2.65	13.0	None
15	Beef liver S Hog liver Hog spleen Salmon viscera Predigested sal. visc. meal	18.1 18.1 18.1 25.7 20.0	2,922	9.72	2.67	12.0	None
16	Beef liver S Hog liver Hog spleen Salmon viscera Sal. visc. meal2/	21.1 21.1 21.1 31.7 5.0	2,887	.86	2.61	13.0	None
17	Beef liver S Hog liver Hog spleen Salmon viscera Sal. visc. meal (vitamin fort.)4/	20.0 20.0 20.0 30.0 10.0	2,934	1.68	2.57	14.3	None
18	Beef liver S Hog liver Hog spleen Salmon viscera Sal. visc. meal (amino acid fort.)5/	20.0 20.0 20.0 30.0 10.0	2,817	1.99	2.64	13.0	None
	Least difference at the 5% confidence level:		143 gr.	.50%			

1/ Salt added at the rate of 2 grams per 100 grams of ration.
2/ Vacuum-dried salmon viscera meal.
3/ Predigested vacuum-dried salmon viscera meal.
4/ Vacuum-dried salmon viscera meal fortified with B complex vitamins.
5/ Vacuum-dried salmon viscera meal fortified with amino acids (lysine and methionine).

beef and hog liver combination (Diet 3). Combinations of beef liver and beef lung (Diet 4) and hog liver and beef lung (Diet 5) also produced gains comprable to the beef and hog liver combination. The hemoglobin content of the blood was lower and the mortality significantly higher in the straight lung diet indicating a possible nutritional deficiency which was not reflected in the growth rate during the first 12-week period. The addition of either beef liver or hog liver to beef lung (Diets 4 and 5) appeared to correct the deficiency while still producing excellent gains. From this experiment it may be concluded that beef lung has a greater growth potential than beef liver and that when combined with either beef or hog liver produces a diet comparable in nutritional adequacy to the beef and hog liver combination. Heretofore the beef and hog liver combination has been recommended as the most satisfactory starting diet for blueback salmon. The results of this experiment indicated that either the beef liver and beef lung or the hog liver and beef lung combinations would be equally as good.

Beef lung has an additional characteristic which recommends it as a diet component. When combined with salt it produces a bound diet which is equal to or better than a similar combination of hog spleen and salt. Hog spleen has been one of the best-binding agents known.

Salmon viscera at the 50 percent level in combination with hog liver (Diet 6), hog liver and hog spleen (Diet 7), and tuna liver (Diet 12) were evaluated by comparison with other hog liver combinations and the standard meat-viscera control (Diet 8). Hog spleen at the 10 percent level was substituted for anequal portion of hog liver in Diet 7 to produce a more tightly bound diet to improve the feeding consistency. The addition of the spleen resulted in no depression of the growth rate and obviously improved the feeding consistency of the diet. The salmon viscera included in Diets 6 and 7 provided an impetus to the growth rate significantly greater than comparable diets which included combinations of hog liver with either beef liver (Diet 3) or beef lung (Diet 5). Either Diet 6 or Diet 7 produced a total gain which was equal to that of the standard meat-viscera mixture. The combination of tuna liver and salmon viscera (Diet 12), however, was inferior to the hog liver and salmon viscera combination (Diet 6). Previous trials indicated that tuna liver at the 100 percent level had an extremely low growth potential but the anti-anemic factor appeared to be present. The results of the present experiment confirmed these indications in that the addition of tuna liver to salmon viscera definitely depressed the growth rate.

It is significant that the hog liver plus salmon viscera (Diet 6) and the hog liver - spleen - viscera (Diet 7) combinations were comparable to the standard meat-viscera control (Diet 8). Previous trials have indicated the possibilities of a hog liver - viscera combination, but heretofore the results have not been such as to provide conclusive proof as to the nutritional adequacy of this combination. The results from this experiment indicated that either the hog liver-viscera or hog liver - spleen - viscera combinations were adequate diets for blueback salmon

when fed for 12 weeks at water temperatures below 45° F. It is doubtful if these combinations would prove generally satisfactory as starting diets for first-feeding fish, because their feeding consistencies are difficult to control. There is, however, every evidence to indicate that they would be excellent as cold-water diets after the fish were feeding well.

The second group of diets were variations of the standard meat-viscera combination. Salmon eggs, either frozen or preserved, were substituted for salmon viscera in Diets 9 and 10 and tuna liver for beef liver in Diet 11. The salmon eggs preserved with 0.5 percent sodium bisulfite had been allowed to stand for three months before being frozen. These eggs differed from those of previous trials (Robinson et al. 1951b) in this respect. In the 1950 trials only the toxicity of the preservative was tested in that the eggs were not allowed to stand for more than two or three days before being refrozen. A comparison of the growth produced by Diets 9 and 10 indicates that an alteration in the growth potential occurred when the eggs were preserved with 0.5 percent sodium bisulfite. Partial decomposition of the eggs was indicated by the partial disintegration of the egg shell, heavy mold formation on the exposed surfaces, and rather putrid odor. The growth response of the fish that were fed the preserved eggs was equal to that of those fed frozen salmon viscera but inferior to that of those fed frozen salmon eggs.

Tuna liver substituted for beef liver in the meat-viscera combination (Diets 8 and 11) proved adequate during the first 12 weeks of feeding. The growth rate on this diet was comparable to that of the meat-viscera mixture and no anemia was indicated.

The third group in this experiment was designed to determine the cause of mortality when meals were included in the diet during prolonged periods of cold-water temperatures. Two hypotheses were advanced as to the cause for this mortality. In the first, it was assumed that a reduction in enzymatic action due to colder temperatures reduced the rate of digestion of the protein. As a result, some of the more slowly liberated amino acids were not made available to the fish. To test this hypothesis, predigested salmon viscera meal was fed at the 10- and 20-percent levels in Diets 14 and 15 for comparison with Diet 13 which contained 10 percent of the standard vacuum-dried salmon viscera meal. The predigested meal, prepared by Halver and Coates of the Western Fish Nutrition Investigations, was enzymatically hydrolyzed by the use of pancreatin and papain then vacuum dried. Digestibility as indicated by formal titration was increased from 11.10 to 21.98 or 91.1 percent. In addition 4 percent methionine and 4 percent lysine were substituted for equal portions of the vacuum-dried salmon viscera meal on the basis of 100 percent meal content (Diet 18). Methionine and lysine were assumed to be the two amino acids which would be the most slowly liberated in the digestion of the meal. The substitution of 10 percent of predigested meal for vacuum-dried meal resulted in a significant increase in

mortality. When 20 percent of predigested meal was used, the mortality was tremendously increased. The amino acid supplemented meal produced a mortality comparable to that of the group fed the vacuum-dried salmon viscera meal. From the results of these experiments, it appears that inhibition of amino acid absorption was not the factor causing the mortality in these diets. More complete experimental data are needed to determine the actual cause of the mortality.

The second hypothesis was based on the assumption that the addition of meal to an otherwise adequate diet inhibited the absorption of or increased the requirement for the vitamins of the B-complex during the cold-water period. In Diet 17 the vacuum-dried salmon viscera meal was fortified with certain vitamins of the B-complex in the following amounts:

Vitamins	Daily Supplement Milligrams per kilogram of body weight
Thiamin hydrochloride	0.196 mgs.
Riboflavin	0.680 mgs.
Nicotinic acid	4.100 mgs.
Pyridoxine hydrochloride	0.590 mgs.
Calcium pantothenate	1.250 mgs.
Biotin	0.077 mgs.
Folic acid	0.295 mgs.

The amount of each vitamin was derived from established maximum requirements for trout as reported by Phillips (1946) and McLaren et al. (1947). Although the resulting mortality was significantly lower than those fed the unfortified diet (Diet 13), it was still significantly higher than the meat-viscera mixture without meal (Diet 8). It is possible that a more complete vitamin supplement might correct the mortality resulting from feeding meals but the results of this experiment are inconclusive.

In Diet 16 the meal content was reduced from 10 to 5 percent. The mortality was significantly reduced below that of the fish fed 10 percent meal (Diet 13) and was comparable to the loss in the meat-viscera control (Diet 8). The total gain in weight of the fish fed 5 percent meal was not significantly different from those fed the 10 percent meal supplements (Diets 13 and 14). All of these diets showed significantly higher gains than the meat-viscera control. The addition of 5 percent meal to the meat-viscera mixture was accompanied by a marked increase in growth rate without a resultant increase in mortality. It is apparent that blueback salmon will both tolerate and utilize a 5 percent addition of vacuum-dried salmon viscera meal to the meat-viscera mixture during the periods of cold water.

During this experiment the mortalities due to the addition of salmon viscera meal at the 10 percent level approximated 2 percent for the 12-week period. These mortalities while significantly different from the

control group do not compare to previous results at Leavenworth in which losses ranged from 18 to 30 percent for a similar 12-week period (Burrows, 1951). The differences in mortality may be attributable to differences in water temperature patterns throughout the period of the experiments. The average water temperatures per biweekly period for 1950 at Leavenworth and for 1951 at Entiat are as follows:

1950:	45.4,	45.1,	44.8,	44.9,	44.5,	47.8,	mean 45.4
1951:	43.0,	43.1,	43.9,	44.9,	45.5,	46.8,	mean 44.5

the 1950 temperature pattern does not differ significantly from those of 1948 and 1949 at Leavenworth. In every instance the temperature either dropped slightly or remained constant during the first 10 weeks of the experimental period. The twelfth biweekly period occurring the last of June was a transitional one in which the water temperature rose rapidly. The 1951 pattern at Entiat differs sharply from those of previous trials in that the temperature was on a slight but consistent upward trend. It is believed that the difference in temperature pattern and the resultant increase in food intake is responsible for the marked reduction in mortality during the 1951 trials. Experiments, using controlled temperature equipment, are planned to test this hypothesis.

The results of the cold-water phase of the first experiment indicated that either the beef liver - beef lung or hog liver - beef lung combinations were diets comparable in nutritional adequacy to the beef liver and hog liver combination -- the most satisfactory starting diet developed to date. A hog liver plus salmon viscera and a hog liver - hog spleen - salmon viscera combination proved comparable to the standard meat-viscera control diet in both their growth potentials and survival rates. These combinations offer excellent possibilities as cold-water diets. Tuna liver in combination with salmon viscera was inferior to the hog liver and salmon viscera combinations but proved an adequate substitute for beef liver in the meat-viscera mixture. Preserved salmon eggs were inferior to frozen eggs but comparable to viscera in growth potential when substituted for these products in variations of the meat-viscera mixture. Neither the substitution of predigested meal for vacuum-dried salmon viscera meal nor the supplementation of the meal with lysine and methionine alleviated the mortality incurred from feeding salmon meals during periods of cold water. The fortification of the meal with vitamins of B-complex reduced the mortality but the results were inconclusive.

First Experiment, 24-Week Period

Certain of the diets of the first experiment were continued an additional 12 weeks making a total of 24 weeks for the experiment. Diets which were of no further interest either because they were primarily cold-water diets which would be too costly to feed when the food intake was high or had been previously tested in warm water were discontinued.

Diet 1 (beef liver) was retained as a control for Diets 2 (beef lung), 6 (hog liver and salmon viscera), and 7 (hog liver - hog spleen - salmon viscera). All of the group testing variations of the meat-viscera combination (Diets 8 through 12) were retained but altered to include 10 percent of vacuum-dried salmon viscera meal during the second 12 weeks. The results for the 24-week period are summarized in Table 3.

The growth rate of the fish fed beef lung (Diet 2) declined sharply during the second 12-week period when compared with the beef-liver control (Diet 1). At the conclusion of the first 12-week period a significant difference in favor of the beef lung diet existed between these lots of fish. After 24 weeks the final weights of the two lots were comparable. Hemoglobin determinations indicated no anemic condition in the beef lung lot. The hog liver plus salmon viscera (Diet 6) and the hog liver - hog spleen - salmon viscera (Diet 7) combinations showed similar gains which were much greater than the beef liver control. A possible anemic tendency in Diet 6 was indicated by the hemoglobin content of the blood taken at the conclusion of the experiment. This result may have been due to a sampling variation or to an inferior feeding consistency. Diet 7 which differed from Diet 6 only by the substitution of 10 percent of hog spleen for hog liver showed no anemia. A comparable ration in the second experiment altered only by the addition of 10 percent meal (Diet 29) did not show the anemic tendency indicated in Diet 6. That the ration itself was adequate for the anti-anemic factors is indicated from the hemoglobin content of the samples taken after the first 12 weeks of feeding. As the fish increased in size and the water temperature rose, the bound quality of the diet may have been inadequate and a loss of a portion of the water soluble components may have been the result. In both Diets 7 and 29 the bound quality of the diet was enhanced either by the addition of a more adequate binding agent -- hog spleen in Diet 7 -- or an absorbing agent -- meal in Diet 29. The chances of the procurement of an aberrant sample appear to be remote. In no other group of 10 fish composing a sample did the hemoglobin content of the blood reach the low level of 7.8 grams per 100 milliliters that was found in 3 of the fish from Diet 6. The evidence indicates an anemic tendency in the fish fed the hog liver plus salmon viscera mixture caused very probably by an inadequate feeding consistency during the second 12-week period.

The meat-viscera combinations were altered after 12 weeks by the addition of 10 percent of vacuum-dried salmon viscera meal and a proportionate reduction in the other diet components. Frozen salmon eggs (Diet 9) were superior to salmon viscera when substituted for viscera in the meat-viscera-meal mixture. Preserved salmon eggs (Diet 10) were inferior to frozen eggs and, when the stored eggs were used, were inferior to salmon viscera. The supply of stored eggs was exhuasted after 16 weeks of feeding and preserved eggs from the 1950 trials were substituted. A marked impetus to the growth rate of the fish was noted when this substitituion was made, sufficient to close the gap between the viscera- and egg-fed fish at the close of the experiment. Tuna liver

TABLE 3.--Summary of 1951 feeding trials with blueback salmon--First Experiment, 24-week period

Initial number per trough: 1,157 fish
Initial weight per trough: 500 gr.

Initial average weight per fish: .43 gr.
Initial number per pound: 1,052 fish

Period: 4/4/51 to 9/10/51

Temperature: Average for 1st 12 wks., 44.5°F; average for 2nd 12 wks., 54.7°F; average for 24 wks., 69.6°F.

Diet No.	Components	Percentage Composition	Mean diet weight at the end of 12 and 24 weeks in grams: 12 wks.	24 wks.	Per cent mortality 12 wks.	24 wks.	Conversion 12 wks.	24 wks.	Hemoglobin g/100 ml. blood 12 wks.	24 wks.	Deficiency Symptoms
1	Beef liver	100.0	2,176	6,066	1.08	2.12	3.19	6.44	13.8	11.8	None
2	Beef lungs S1/	100.0	2,402	6,002	1.90	3.33	2.99	6.96	10.7	11.6	None
6	Hog liver S Salmon viscera	50.0 50.0	2,740	8,920	.99	1.90	2.75	3.66	13.0	9.2	Possible anemic tendency after 24 weeks of feeding.
7	Hog liver S Hog spleen Salmon viscera	40.0 10.0 50.0	2,744	9,072	1.38	2.07	2.76	3.65	12.5	10.9	None
8 2/	Beef liver S Hog liver Hog spleen Salmon viscera	22.2 22.2 22.2 33.4	2,668	12,612	.95	1.43	2.79	2.79	14.1	11.7	None
9 2/	Beef liver S Hog liver Hog spleen Salmon eggs (frozen)	22.2 22.2 22.2 33.4	2,854	14,194	1.38	2.42	2.66	2.65	13.8	12.2	None
10 2/	Beef liver S Hog liver Hog spleen Preserved salmon eggs	22.2 22.2 22.2 33.4	2,606	12,526	1.25	2.03	2.79	2.89	12.0	11.2	None
11 2/	Tuna liver S Hog liver Hog spleen Salmon viscera	22.2 22.2 22.2 33.4	2,584	10,606	1.21	2.03	2.87	3.25	12.8	12.7	None
	Least difference at the 5% confidence level:		143 grs. 12 weeks	254 grs. 24 weeks	.50%	1.64%					

1/ Salt added at the rate of 2 grams per 100 grams of ration.

2/ At the end of the first 12-week period 10% of vacuum-dried salmon viscera meal was added to these diets with a corresponding proportional reduction in each of the original components.

proved inferior to beef liver in its growth potential when substituted in the meet-viscera-meal mixture (Diets 8 and 11). No anemia had developed in these fish at the end of 24 weeks of feeding.

From the results of these feeding trials it may be concluded that beef lung contained adequate amounts of the anti-anemic factor to support blueback salmon for a 24-week period. A hog liver and salmon viscera combination produced an excellent diet with the exception of an inferior feeding consistency during warm-water periods. This feeding consistency may be improved by the addition of either hog spleen or salmon meal. Salmon eggs preserved by the addition of 0.5 percent sodium bisulfite and held at room temperatures for 90 days did not produce gains comparable to a similar diet containing fresh frozen eggs. Partial decomposition of the eggs during storage was probably responsible for the reduction in growth. Tuna liver proved an inadequate substitute for beef liver in the meat-viscera-meal mixture in that a reduction in growth rate resulted.

Second Experiment

The second experiment conducted with blueback salmon was begun in July after the first 12-week period of the first experiment was concluded. Information gained in the first experiment was used to develop certain of the diets fed in the second experiment.

These feeding trials were, on the whole, more exploratory in nature than the first experiment. The trials consisted of evaluations of single components, substitutions of these components for beef liver or hog spleen in the meat-viscera-meal mixture, and tests of whale meal, salmon viscera, and salmon viscera meal in combination with various meat and fish products. The results of the second experiment are summarized in Table 4.

The liver of the finback whale (Balaenoptera physalus), supplied fresh frozen through the courtesy of the British Columbia Packers Association, was the source of the whale liver used in these experiments. The intent of the experiments with whale liver was to determine its possibilities as a substitute for beef liver. The use of whale liver as a source of fish food had not been previously evaluated.

Arrow-toothed halibut (Atheresthes stomias) was fed to determine its growth potential. This species is a scrap fish occurring abundantly on the Pacific Coast where it is taken in the trawl fishery and discarded. it would offer a cheap, reliable source of fish food. No tests of arrow-toothed halibut have been made except as they have been included incidentally in scrap ocean fish such as was reported by Wales (1944).

Herring (Clupea pallasii) was included in the diet studies to determine its growth potential and nutritional adequacy for salmon. Herring, not specifically identified, has been fed to trout on the

TABLE 4.--Summary of 1951 feeding trials with blueback salmon--Second Experiment, 12-week period

Initial number per trough: 363 fish
Initial weight per trough: 1,000 gr.
Initial average weight per fish: 2.75 gr.
Initial number per pound: 165 fish
Period: 7/4/51 to 9/25/51
Temperature: Average for 12 weeks, 55.5°F.

Diet No.	Components	Percentage Composition	Mean diet weight at the end of 12 weeks in grams	Per cent mortality 12 weeks	Conversion 12 weeks	Hemoglobin g/100 ml. blood 12 weeks	Deficiency Symptoms
19	Beef liver	100.0	2,731	.41	4.54	10.3	None
20	Whale liver	100.0	1,038	3.72 Diet discontinued 7/31/51	48.47	11.5	Fish thin, almost emaciated; usually one operculum hemorrhagic; one or more gill arch bearing fungus; gill lamellae malformed, some swollen, some curled, some proliferated, some entirely eroded away; livers pale; intestinal fat slight or lacking.
21	Arrow-toothed halibut	100.0	3,301	.55	3.58	10.2	None
22	Herring	100.0	3,801	1.65	3.37	8.9	Fish fat in appearance, dark in color, weak and listless; head usually retracted; some exhibiting loss of equilibrium; some suffering violent nervous convulsions when startled; livers pale yellow to yellowish brown in color; intestinal fat heavy.
23	Beef liver S 1/ Hog liver Hog spleen Salmon viscera Sal. visc. meal 2/	20.0 20.0 20.0 30.0 10.0	4,164	.14	2.99	12.5	None
24	Beef liver S Hog liver Hog spleen Salmon viscera Whale meal	20.0 20.0 20.0 30.0 10.0	4,331	.14	2.89	13.0	None
25	Whale liver S Hog liver Hog spleen Salmon viscera Sal. visc. meal 2/	20.0 20.0 20.0 30.0 10.0	3,873	.83	3.37	11.7	None
26	Beef liver S Hog liver Beef lung Salmon viscera Sal. visc. meal	20.0 20.0 20.0 30.0 10.0	4,156	.41	2.96	12.8	None
27	Beef liver S Hog liver Arrow-toothed halibut Salmon viscera Sal. visc. meal	20.0 20.0 20.0 30.0 10.0	4,558	.96	2.74	13.3	None
28	Beef liver S Hog liver Herring Salmon viscera Sal. visc. meal	20.0 20.0 20.0 30.0 10.0	4,739	.69	2.35	13.3	None
29	Hog liver S Salmon viscera Sal. visc. meal	45.0 45.0 10.0	4,583	.55	2.79	12.5	None
30	Beef lung S Salmon viscera Sal. visc. meal	45.0 45.0 10.0	3,994	1.65	3.06	12.2	None
31	Tuna liver S Salmon viscera Sal. visc. meal	45.0 45.0 10.0	2,428	12.40 Diet discontinued 8/28/51	3.64	13.6	Fish fat in appearance; one or more gill arch bearing fungus; gill lamellae malformed, some swollen, some severely proliferated, some entirely eroded away; livers pale, swollen; intestinal fat heavy.
32	Hog liver S Beef lung Salmon viscera Sal. visc. meal	22.5 22.5 45.0 10.0	4,418	.69	2.84	12.7	None
	Least difference at the 5% confidence level:		365.6 grs.	1.07%			

1/ Salt added at the rate of 2 grams per 100 grams of ration.

2/ Vacuum-dried salmon viscera meal.

seaboard but according to Atkins (1908) and Titcomb et al. (1929) the results were not conclusive. Frozen herring in the round is a cheap available source of fish food on the Pacific coast.

The first group of diets in the second experiment were single component rations. In these studies the intent was to measure the potentialities of the individual products not for use as production diets but as possible supplements to other combinations. Whale liver (Diet 20), arrow-toothed halibut (Diet 21), and herring (Diet 22) were fed as unsupplemented rations for comparison with beef liver (Diet 19). The whale-liver diet was discontinued after 4 weeks due to a high mortality. It was indicated that this toxic effect was produced by an excess of vitamin A in the whale liver. Both arrow-toothed halibut and herring proved to have a higher growth potential than beef liver with herring being superior to halibut. In the herring-fed fish, symptoms of a thiamin deficiency were discernible after 6 weeks of feeding and were very pronounced at the conclusion of the experiment. No such symptoms occurred in the fish fed the arrow-toothed halibut.

In the second group of trials various substitutions were made in the standard meat-viscera-meal mixture. In Diet 24 whale meal was substituted for salmon viscera meal. This whale meal was an especially-prepared, low-temperature-dried product supplied by the Seattle Technological Laboratory of the Fish and Wildlife Service. The growth response of the fish on the diet containing whale meal was comparable to that of those fed salmon viscera meal. Whale meal appeared to be an adequate substitute for salmon viscera meal. Because of the growth stimulus supplied by the low-temperature-dried whale meal it is proposed to test a commercially-prepared, flame-dried whale meal next season.

Whale liver (Diet 25) substituted for beef liver in the meat-viscera-meal mixture produced an adequate diet when fed for a 12-week period. The growth rate was comparable to the control (Diet 23) and no anemia was indicated. Because of the results of the single component studies, however, in which whale liver produced an acute toxicity, it is doubtful if whale liver would be a safe product to include in production diets.

Beef lung was substituted for hog spleen in Diet 26. This substitution was based on the results of the 12-week period of the first experiment. The growth rate on this diet was practically identical to that of the fish fed the control diet. The mortalities were not significantly different and the hemoglobin content of the blood was comparable. If anything the bound quality of this diet was better than that of the control. Because of its cheaper price and equal nutritional adequacy, the substitution of beef lung for hog spleen in the meat-viscera-meal mixture can be recommended.

Previous experiments with ocean fish sbustituted for various products in the meat-viscera-meal mixture indicated that the deletion of spleen

and substitution of the fish produced the greatest growth resonse. For this reason both arrow-toothed halibut and herring were substituted for spleen in different diets. The substitution of arrow-toothed halibut (Diet 27) resulted in a marked acceleration in the growth rate of the fish significantly more than those fed the hog spleen (Diet 23). No nutritional deficiencies were apparent in this diet. Because of the deletion of spleen the bound quality of the diet was greatly impaired and leaching of the water soluble components of the diet was obvious. Some alteration in this diet is indicated to improve its feeding consistency. The growth response of the fish fed the herring ration (Diet 28) was slightly but not significantly greater than that of those fed arrow-toothed halibut. It will be recalled that the growth rate of the fish which were fed herring as the entire ration (Diet 22) was significantly higher than that of those fed arrow-toothed halibut (Diet 21). The trend indicated in the composite diets and the significant difference displayed in the single component studies leads to the conclusion that herring has a higher growth potential than does halibut. In the composite diet the possible thiamin deficiency in the herring was adequately covered by the other components. It is entirely possible that the thiamin content of herring is not low, but that the thiamin deficiency induced in experimental fish fed herring was the result of a thiaminase enzyme which destroys the thiamin present. The feeding consistency of Diet 28 was inferior to that of the meat-viscera-meal mixture. To make good production diets, either of these rations should be altered to include a more adequate binding agent.

In this group of diets the beef liver, hog liver, beef lung, salmon viscera, and meal combination appears to be the most adequate substitute for the standard meat-viscera-meal combination. The substitution of either herring or arrow-toothed halibut for spleen offers excellent possibilities providing that these diets are handled and fed very carefully to prevent excessive leaching. In actual production operations, it is doubtful if these diets would prove adequate until the feeding consistency is improved by the addition of more adequate binding agents. Whale liver, because of its high vitamin A content and the danger of the creation of a hypervitaminosis in the fish, is not recommended as a diet component. The low-temperature-dried whale meal is an adequate substitute for vacuum-dried salmon viscera meal. Should this product become available commercially, its use in production diets could be recommended.

The third group of diets in the second experiment was designed to develop a low cost ration for salmon for use during warm-water periods. In these diets salmon viscera, 45 percent, and salmon viscera meal, 10 percent, were used as the base. Hog liver (Diet 29), beef lung (Diet 30), tuna liver (Diet 31), and equal parts of hog liver and beef lung (Diet 32) were used as supplements to this base.

The hog liver plus salmon viscera diet fed in the first experiment (Diet 6) was supplemented with 10 percent of salmon meal to form Diet 29

in the second experiment. This diet demonstrated an excellent growth potential and an anti-anemic quality. The growth was significantly greater than that of the meat-viscera-meal control, and the hemoglobin content of the blood at the conclusion of the experiment was comparable to the control. This diet has a good feeding consistency and can be recommended for production use.

In Diet 30, beef lung was substituted for hog liver to supplement the salmon viscera-meal base. The growth produced by this diet was comparable to the meat-viscera-meal control (Diet 23) but significantly less than that of the hog-liver supplement (Diet 29). Hemoglobin determinations from samples of these fish indicated an absence of anemia. The mortality, however, was significantly higher in this diet than in either Diet 23 or 29 and was slightly increasing toward the conclusion of the experimental period. No deficiency symptoms were discernible by either macroscopic or microscopic examination. The significance of mortality difference was borderline at the 5-percent level and insignificant at the 1-percent level. [The data were analyzed statistically by use of analysis of variance for paired experiments as outlined by Snedecor (1940, 1946).] The absence of an anemia or other recognizable deficiency symptoms and the borderline character of the mortality difference lends credence to the belief that this mortality was not indicative of a dietary deficiency. The beef lung created an extremely tight bind when combined with salt to produce a diet of excellent feeding consistency. This diet because of its low cost, excellent feeding consistency, and good growth potential can be recommended as a production diet during warm-water periods.

The addition of tuna liver to the viscera-meal base (Diet 31) produced an unsatisfactory ration. The diet was discontinued after 8 weeks of feeding due to an excessive mortality probably caused by a hypervitaminosis A.

A combination of equal parts of hog liver and beef lung as a supplement to the viscera-meal base produced an excellent diet. The growth rate of these fish was comparable to those fed the meat-viscera-meal control (Diet 23). No symptoms of nutritional deficiencies were discernible. The feeding consistency due to the addition of beef lung was excellent.

From this group three diets appear to have excellent possibilities as production diets: the hog liver and salmon viscera meal combination, the beef lung and salmon viscera meal combination, and the hog liver - beef lung - salmon viscera meal combination. This latter combination is the best of the group when the final cost per pound of fish is used as the measure of efficiency. Using the same criterion, all of these diets are superior to the standard meat-viscera-meal combination when fed to blueback salmon.

Analyses of the vitamin A content of the standard meat-viscera-meal control (Diet 23), whale liver (Diet 20), and the tuna liver - salmon viscera meal diet (Diet 31) indicate the possibility of a hypervitaminosis A being responsible for the high mortality encountered in the whale liver and tuna liver diets. Results of the analyses made by the Seattle Technological Laboratory of the Fish and Wildlife Service are as follows:

Diet No.	Oil Content	Spectrophotometric units per gram of oil	Spectrophotometric units per 100 grs. diet
20 (whale liver)	3.37%	94,200	317,454
31 (tuna liver)	2.94%	19,965	58,697
23 (control)	6.15%	4,400	27,060

It will be noted that the vitamin A content of Diets 20 and 31 was much higher than that encountered in Diet 23 the standard control. A high mortality, sufficient to force a discontinuation of the experiments, occurred in Diet 20 after 4 weeks of feeding and Diet 31 after 8 weeks of feeding. Hypervitaminosis A has not been reported previously in salmon but has been produced in both man and rats. The work of Rodahl as reported by Marier (1951) is particularly pertinent in that he was able to demonstrate hypervitaminosis A by feeding whale-liver oil to rats. All the evidence strongly supports the hypothesis that a hypervitaminosis A was present in the fish which were fed diets containing high levels of either whale or tuna liver.

The results of the second experiment indicated that whale liver had few possibilities as a diet component for blueback salmon because of its high vitamin A content. Both herring and arrow-toothed halibut when substituted for hog spleen in the meat-viscera-meal combination produced a significant increase in the growth rate of the fish but the diet consistency was poor. Of the two, herring appeared to have a higher growth potential than the halibut. Low-temperature-dried whale meal was an adequate substitute for vacuum-dried salmon viscera meal. Beef lung substituted for hog spleen in the meat-viscera-meal mixture produced a combination equal to the standard control. The addition of hog liver, beef lung, or a combination of hog liver and beef lung to salmon viscera and salmon viscera meal produced combination diets equal to or better than the standard meat-viscera-meal control. Tuna liver in a similar combination was unsatisfactory due to the development of a hypervitaminosis A.

Third Experiment

Although no controlled-feeding trials had been conducted previously on chinook salmon at the Salmon-Cultural Laboratory, in regular production feeding a difference in nutritional requirements appeared to exist between chinook and blueback salmon. Chinook, when fed the standard meat-viscera mixture, developed an acute anemia in at least a portion of each lot fed. This condition did not develop in blueback fed an

identical diet or one supplemented by 10 percent meal. It was assumed that the anemia was caused by a difference in the nutritional requirements of chinook. To increase the vitamin content of the diet, the hog spleen was eliminated from the meat-viscera mixture and a diet consisting of one third each of beef liver, hog liver, and salmon viscera was created. This diet was fed for the last two years to the production chinook and the fish did not develop an anemia. As this ration was fed during different years and to different stocks of fish without adequate control groups, numerous variables were introduced which made it impossible to draw any conclusions from the results. The chinook experiments conducted this season were designed to determine if nutritional differences existed between chinook and blueback salmon.

On the assumption that nutritional deficiencies would develop, the standard meat-viscera mixture (Table 5, Diet 1-C) was supplemented with 5 percent of crab meal (Diet 2-C). The work of McLaren (1947) indicated that crab meal might contain some unknown nutrient essential to the normal development of rainbow trout. Experiments at this laboratory (Robinson et al. 1951a, 1951b) indicated that crab meal contained some anti-anemic properties when fed to blueback salmon. The total scrap of the blue crab (Callinectes sapidus) was the source of this flame-dried meal. The chinook ration (Diet 3-C), consisting of one third each of beef liver, hog liver, and salmon viscera was fed for purposes of comparison with the meat-viscera control (Diet 1-C). The chinook ration was supplemented with 10 percent of vacuum-dried salmon viscera meal (Diet 4-C) during the second 12 weeks of feeding and with 5 percent of crab meal (Diet 5-C) for the entire period. The salmon meal supplement was added to determine if the addition of this meal would be a contributory factor in the development of an anemia. Salmon eggs were substituted for salmon viscera in the chinook ration (Diet 6-C) to measure the contribution of eggs in this combination.

The results of these feeding trials were not as anticipated. The standard meat-viscera control (Diet 1-C) proved entirely adequate for chinook salmon. The rate of growth was significantly greater than that of the fish fed the chinook ration (Diet 3-C) and no anemia was indicated. Crab meal made no measurable contribution to the growth rate or hemoglobin content of the blood in either the supplemented meat-viscera mixutre (Diet 2-C) or the chinook ration (Diet 5-C). The variation in hemoglobin content which appears to exist is believed to be but a normal biological variation since no anemic fish were encountered in any of these diets. The addition of vacuum-dried salmon-viscera meal to the chinook ration resulted in a significant increase in the growth rate without the development of an anemia. Salmon eggs substituted for salmon viscera in the chinook ration (Diet 6-C) did not result in an additional growth response. The failure of salmon eggs to increase the growth rate is believed to be due to the poor feeding consistency of the diet rather than the inability of the fish to utilize the protein.

TABLE 5.—Summary of 1951 feeding trials with chinook salmon—Third Experiment, 24-week period

Initial number per trough: 325 fish
Initial weight per trough: 500 gr.

Initial average weight per fish: 1.54 gr.
Initial number per pound: 295 fish

Period 5/5/51 to 9/18/51

Temperature: Average 1st 12 wks., 44.5°F; average 2nd 12 wks., 54.7°F; average for 24 wks., 49.6°F.

Diet No.	Components	Percentage Composition	Mean diet weight at the end of 12 weeks in grams	Mean diet weight at the end of 24 weeks in grams	Per cent mortality 12 wks.	Per cent mortality 24 wks.	Conversion 12 wks.	Conversion 24 wks.	Hemoglobin g/100 ml. blood 24 weeks	Deficiency Symptoms
1-C	Beef liver S1/ Hog liver Hog spleen Salmon viscera	22.2 22.2 22.2 33.4	1,893	3,516	.62	1.54	2.56	4.37	14.1	None
2-C	Beef liver S Hog liver Hog spleen Salmon viscera Crab meal	21.1 21.1 21.1 31.7 5.0	1,779	3,461	.62	1.08	2.71	4.40	13.3	None
3-C	Beef liver S Hog liver Salmon viscera	33.3 33.3 33.4	1,814	3,086	.92	3.23	2.66	4.95	11.7	None
4-C2/	Beef liver S Hog liver Salmon viscera	33.3 33.3 33.4	1,728	3,738	.31	.77	2.75	3.76	12.2	None
5-C	Beef liver S Hog liver Salmon viscera Crab meal	31.66 31.66 31.68 5.00	1,694	3,109	.46	1.54	2.80	4.77	13.4	None
6-C	Beef liver S Hog liver Salmon eggs (frozen)	33.3 33.3 33.4	1,854	3,196	.92	1.38	2.55	4.86	13.6	None
	Least difference at the 5% confidence level:		209 grs. 12 weeks	328 grs. 24 weeks	.66%	3.27%				

1/ Salt added at the rate of 2 grams per 100 grams of ration.

2/ At the end of the first 12-week period 10% of vacuum-dried salmon viscera meal was added to these diets with a corresponding proportional reduction in each of the original components.

The differences in nutritional requirements between chinook and blueback salmon do not appear to be as great as was indicated in production feeding. The failure of the standard meat-viscera mixture to maintain chinook salmon in actual production operations without an anemia developing in at least a portion of the stock may have been due to several causes: (1) The spring and summer races of chinook may have been inadequately separated with a resultant retention of the spring stock past their normal migration period; (2) some unrecognized variation in hatchery techniques or unfavorable environmental condition may have been active; or (3) an inherent physiological defect within certain of the fish in a lot may have been present causing a malfunction of the hematopoietic system and subsequent anemia. The latter hypothesis seems to have the most general substantiation in fact, although in certain instances the other factors may have been responsible for the anemia.

Summary of Results

Under the conditions of these experiments using blueback and chinook salmon as the test animals, the following conclusions were reached:

1. Beef lung was an adequate substitute for hog spleen in the standard meat-viscera mixture. Its binding qualities were as good or better than spleen, and its growth potential appeared to be equal in this combination. When combined with hog liver, salmon viscera, and salmon viscera meal, it produced a diet equal in every respect to standard meat-viscera-meal combination. In addition to its compatability in combination diets, the low initial costs of beef lung makes it a valuable addition in production diets.

2. Whale liver proved unsatisfactory when fed at the 100 percent level. The mortality which resulted from feeding this diet was indicated to be caused by a hypervitaminosis A. When substituted for beef liver in the meat-viscera-meal mixture, whale liver proved adequate. The growth response was comparable and no anemia developed. Because of the danger of the development of a hypervitaminosis A and the variability in the vitamin A content of different livers, whale liver should be used with caution. Its use in production diets is not recommended.

3. Arrow-toothed halibut proved an adequate substitute for hog spleen in the meat-viscera-meal mixture. The growth rate was comparable but the bound quality of the diet was impaired. At the 100 percent level its growth potential was inferior to herring. Other combinations, including arrow-toothed halibut, must be tested before it can be recommended for production use.

4. Herring substituted for spleen in the meat-viscera-meal combination resulted in a significant acceleration in the growth rate of the fish when compared with the standard combination diet. Here, again, the bound quality of the diet was impaired. When used at the 100 percent level, fish which were fed herring developed symptoms indicating a thiamin

deficiency. In the combination diet this deficiency appeared to be adequately covered. Because of the excellent growth potential of herring, further experimentation might determine proper combinations which would improve the feeding consistency yet retain the growth advantage.

5. A hog liver plus salmon viscera and a hog liver and salmon viscera meal combination were adquate substitutes for the meat-viscera and meat-viscera-meal control diets. These diets produced growth rates as good or better than their comparable controls. They have excellent possibilities as production diets.

6. Tuna liver substituted for beef liver in the meat-viscera control diet produced comparable gains during the cold water period but resulted in a significantly lower growth rate during the warm water period when 10 percent meal was added to both diets. No anemia developed during the 24-week feeding period. A tuna liver and salmon viscera meal combination resulted in an acute hypervitaminosis A after 8 weeks of feeding. Tuna liver because of its low growth potential and high vitamin A content is not recommended for inclusion in production diets.

7. Salmon eggs, preserved with 0.5 percent sodium disulfite and stored at room temperatures for 3 months before being frozen, lost a portion of their growth potential.

8. Attempts to reduce mortality due to feeding 10 percent of salmon meal during prolonged periods of cold water produced, in the main, negative results. Predigested salmon-viscera meal and the vacuum-dried product fortified with 4 percent each of lysine and methionine did not reduce the mortality, rather the predigested meal aggravated it. The addition of B-complex vitamins to the diet caused a significant reduction in the mortality, but the losses were still significantly higher than those of the control lot. A 5 percent meal content in the diet caused a significant increase in growth rate without an increase in mortality over the control. A more complete vitamin supplementation may prove the key to mortalities when high-protein diets are fed during periods of prolonged cold water.

9. In experiments with chinook salmon it was impossible to demonstrate a difference between the nutritional requirements of chinook and blueback salmon. The standard meat-viscera mixture used for blueback proved entirely adequate for chinook. The addition of 10 percent meal to the chinook diet (one third each of beef liver, hog liver, and salmon viscera) resulted in a significant acceleration in growth rate with no anemia when fed during the warm-water period.

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